GPS radio occultation as part of the global observing system for atmosphere

A. J. Mannucci, C. O. Ao, B. A. Iijima, B. D. Wilson, and T. P. Yunck

Jet Propulsion Laboratory, California Institute of Technology

E. R. Kursinski

U. Arizona

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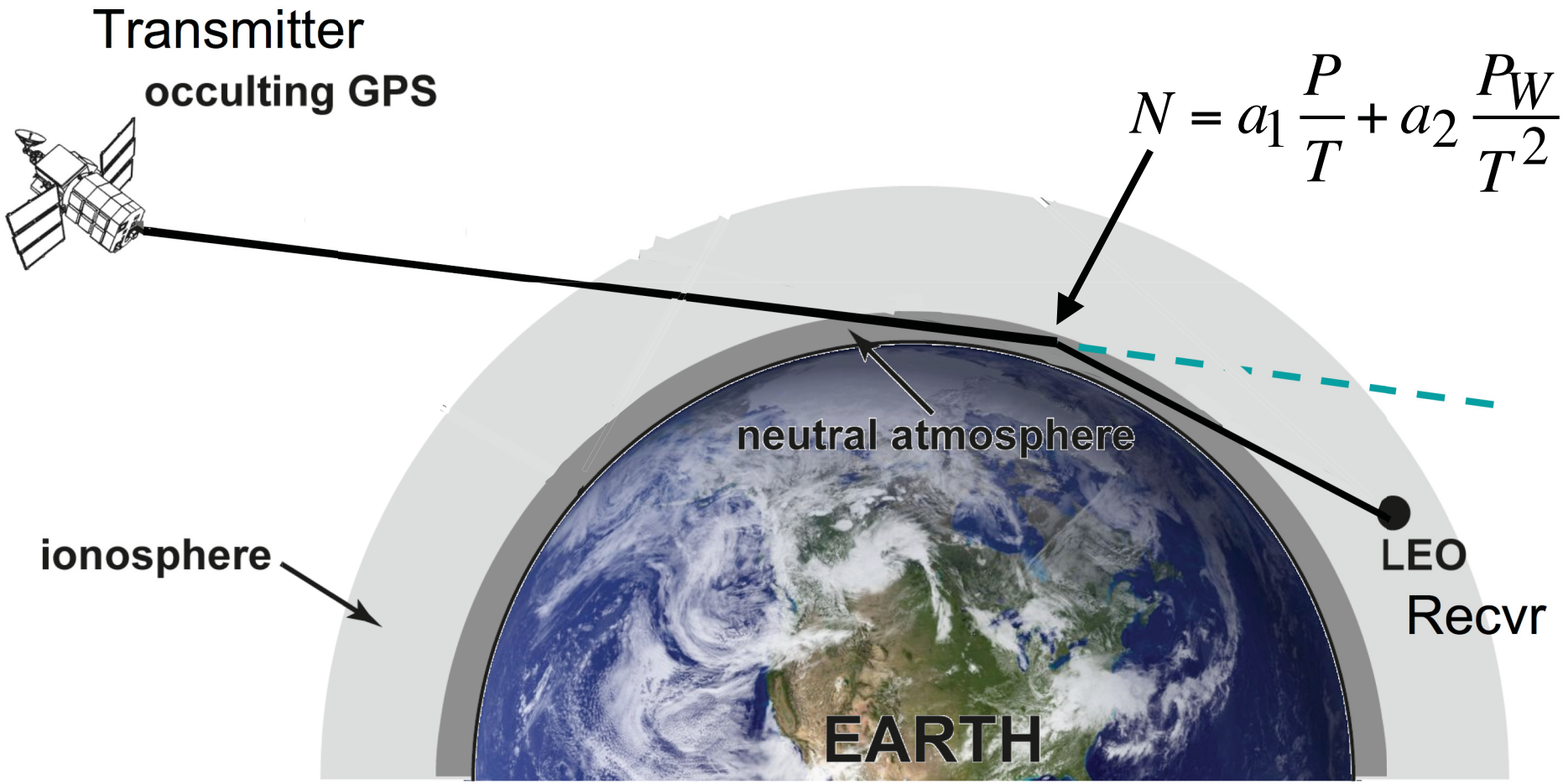
Overview of Today's Talk

- The Measurement
  - Physical retrievals based on time standards
- GPS Retrieval Products
- Retrievals and Radiances: CLARREO Mission
- GPS RO and AIRS
- GPS RO and Microwave
- GPS RO and Radiosondes
- GPS/GNSS Science
- Conclusions

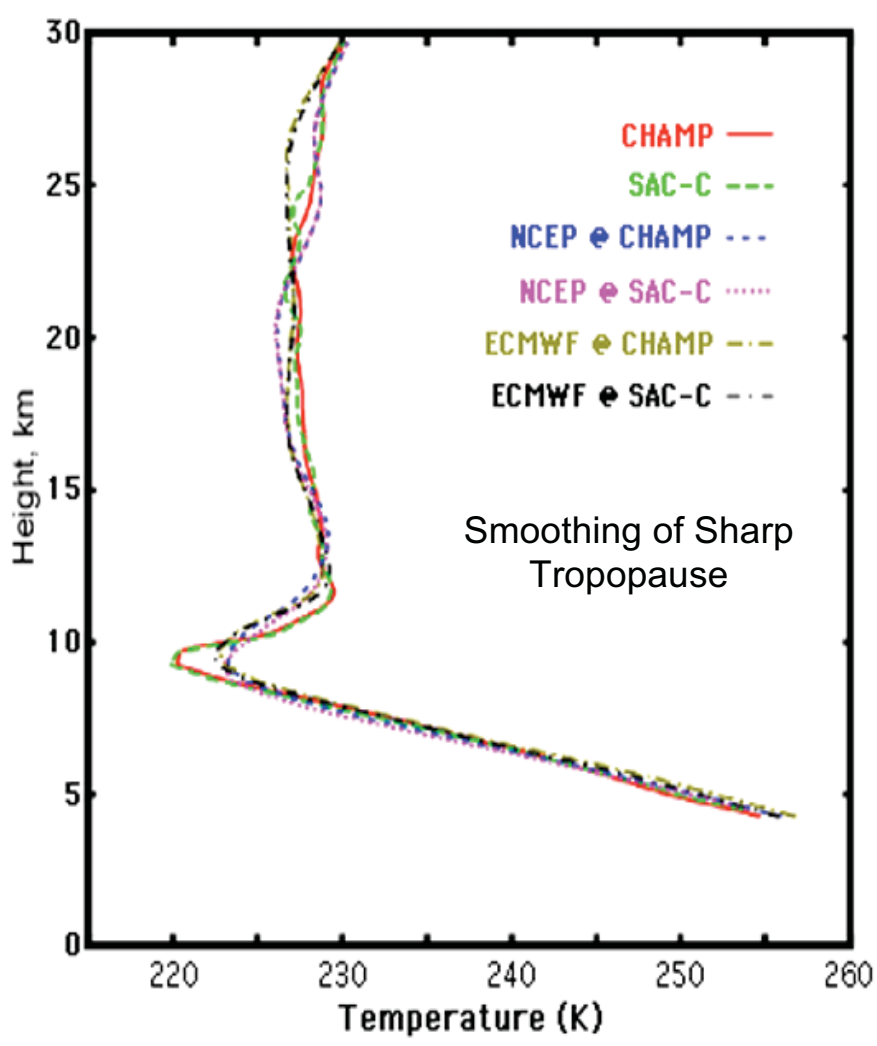
The Radio Occultation Measurement

Geometry of an acquisition

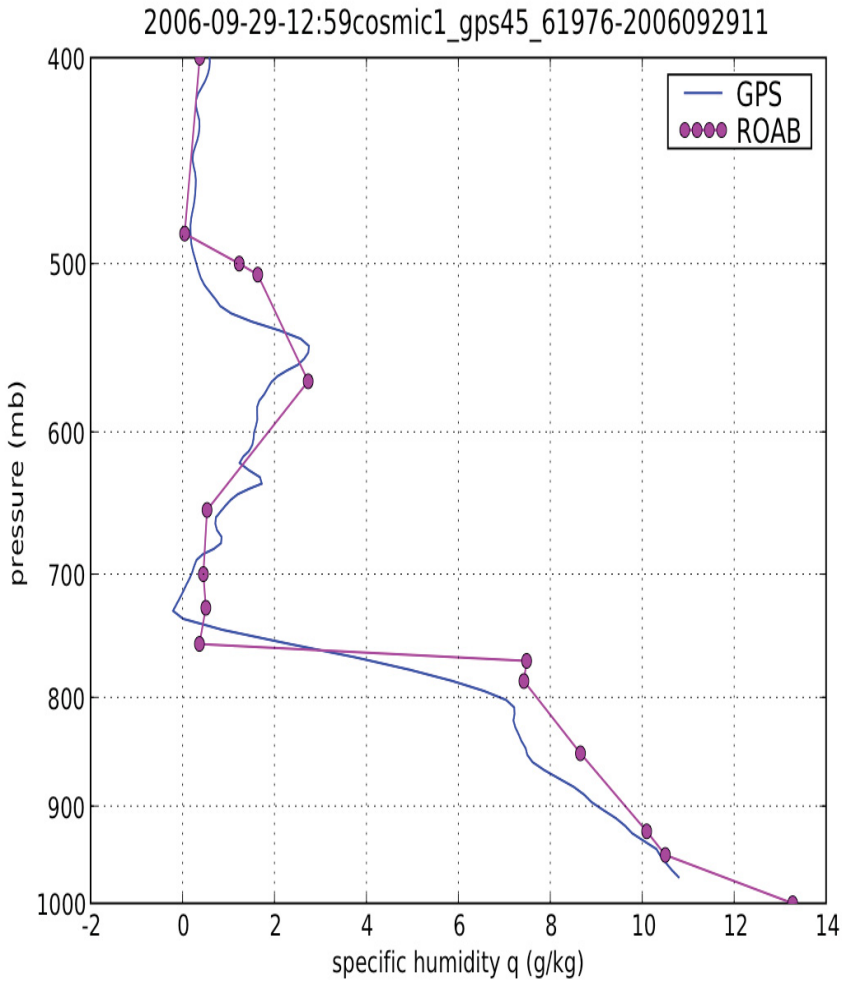


GPS RO Retrievals

Temperature



Water Vapor



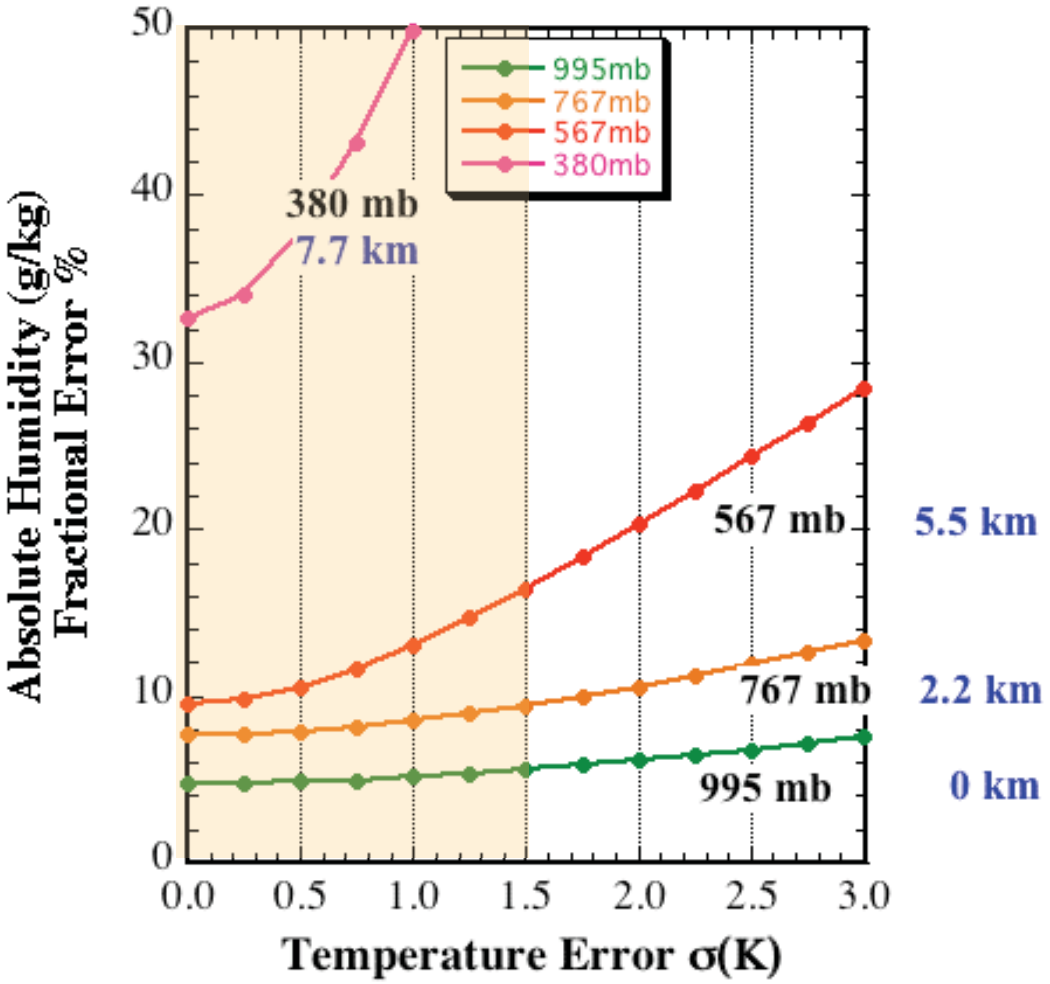
Retrieval Products

- **Refractivity *vs* altitude**
- **Density *vs* altitude (> 7 km)**
- **Temperature *vs* altitude**
  - **Assumes hydrostasis**
- **Pressure vs altitude**
  - **Assumes hydrostasis**
- **Water vapor**
  - **Assumes T/P**

- **Climate benchmarks:**
  - **Refractivity above PBL**
  - **Temperature 8-25 km**

$$N = a_1 \frac{P}{T} + a_2 \frac{P_W}{T^2}$$

Humidity Versus Temperature Uncertainty

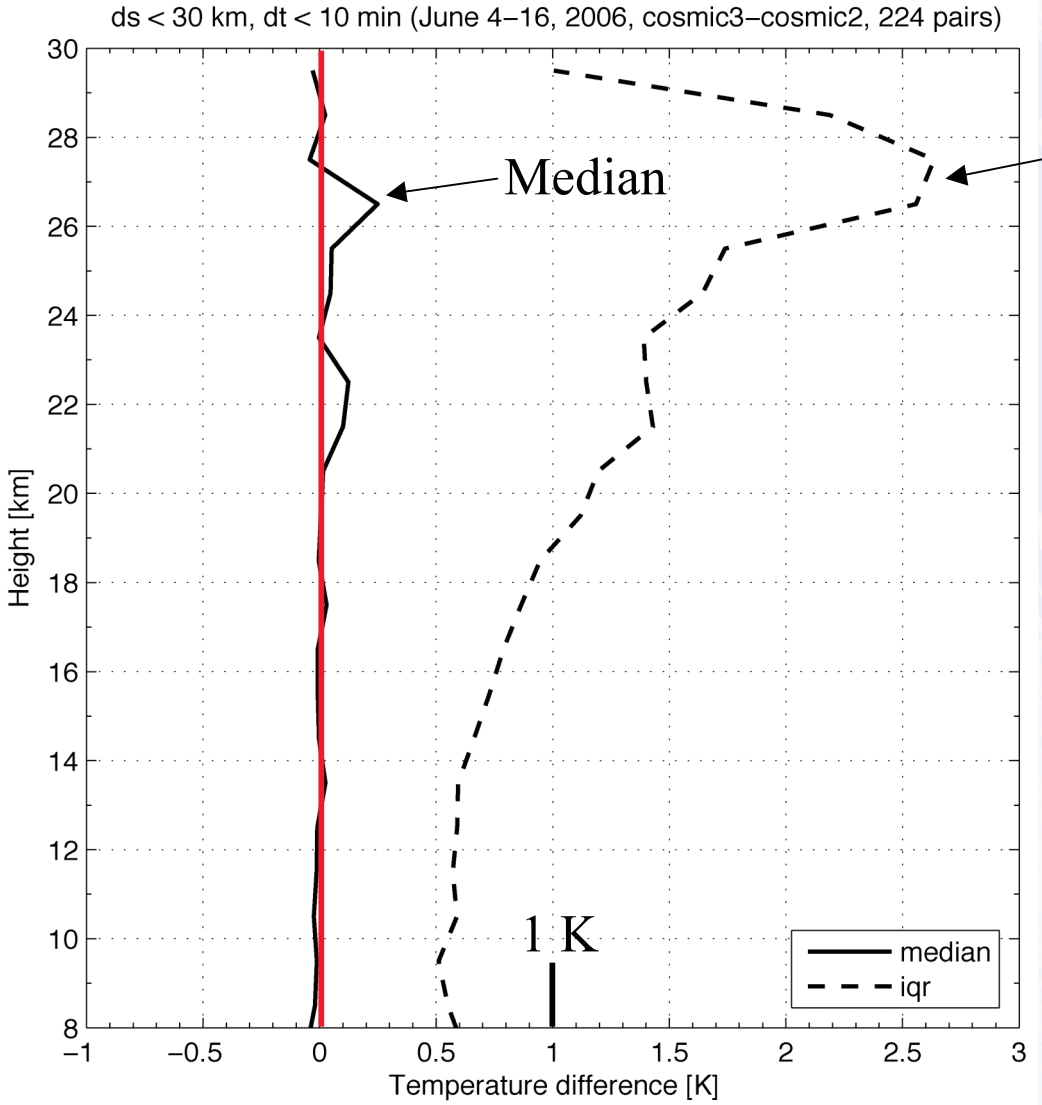


Kursinski et al., *GRL* 1995, *JGR* 2001

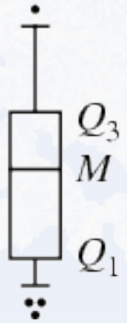
COSMIC-to-COSMIC

COSMIC3 - COSMIC2

Window:
30 km
10 minutes
June 4-16, ‘06
224 pairs



Contains central 50% of differences



Decadal Survey Mission
CLARREO

Objective: *SI-traceable* measurements to compare with climate model output and improve climate predictions

Requirements Driver: "Societal benefit"

Infrared radiance – *Forcing*

- **Annual mean brightness temperature**
- **15-degree grid**
- **0.1 K accuracy**
- **Spectrally resolved (1 cm^{-1})**

GPS refractivity profiles – *Response*

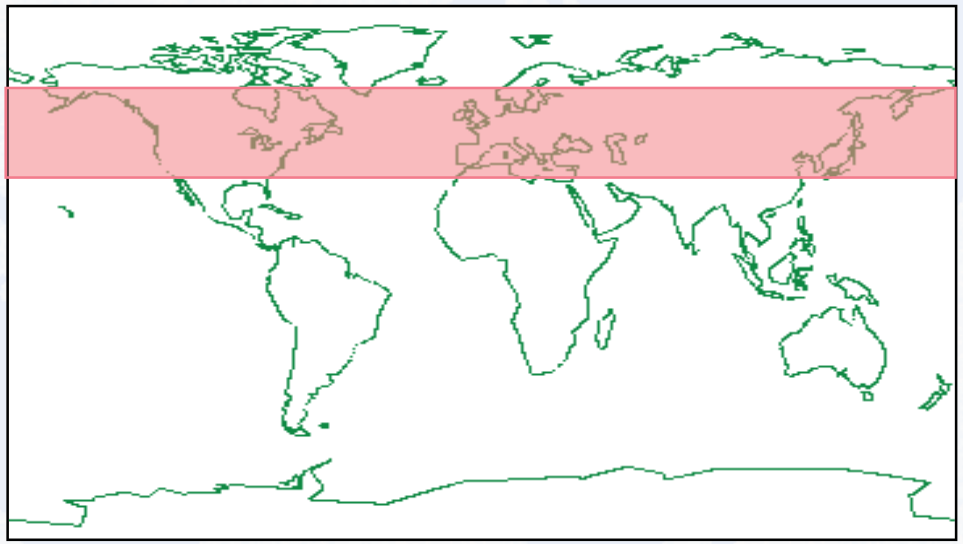
- **Refractivity profiles**
- **0.1 K equivalent temperature accuracy**
  - **0.05% absolute accuracy**

“How does a particular observing system mesh with others?”

Retrieval Comparisons
AIRS – ECMWF – GPS

- AIRS-ECMWF-GPS temperatures
- Common set of 3-way match-ups
- For all of 2003 (Champ, SAC-C)

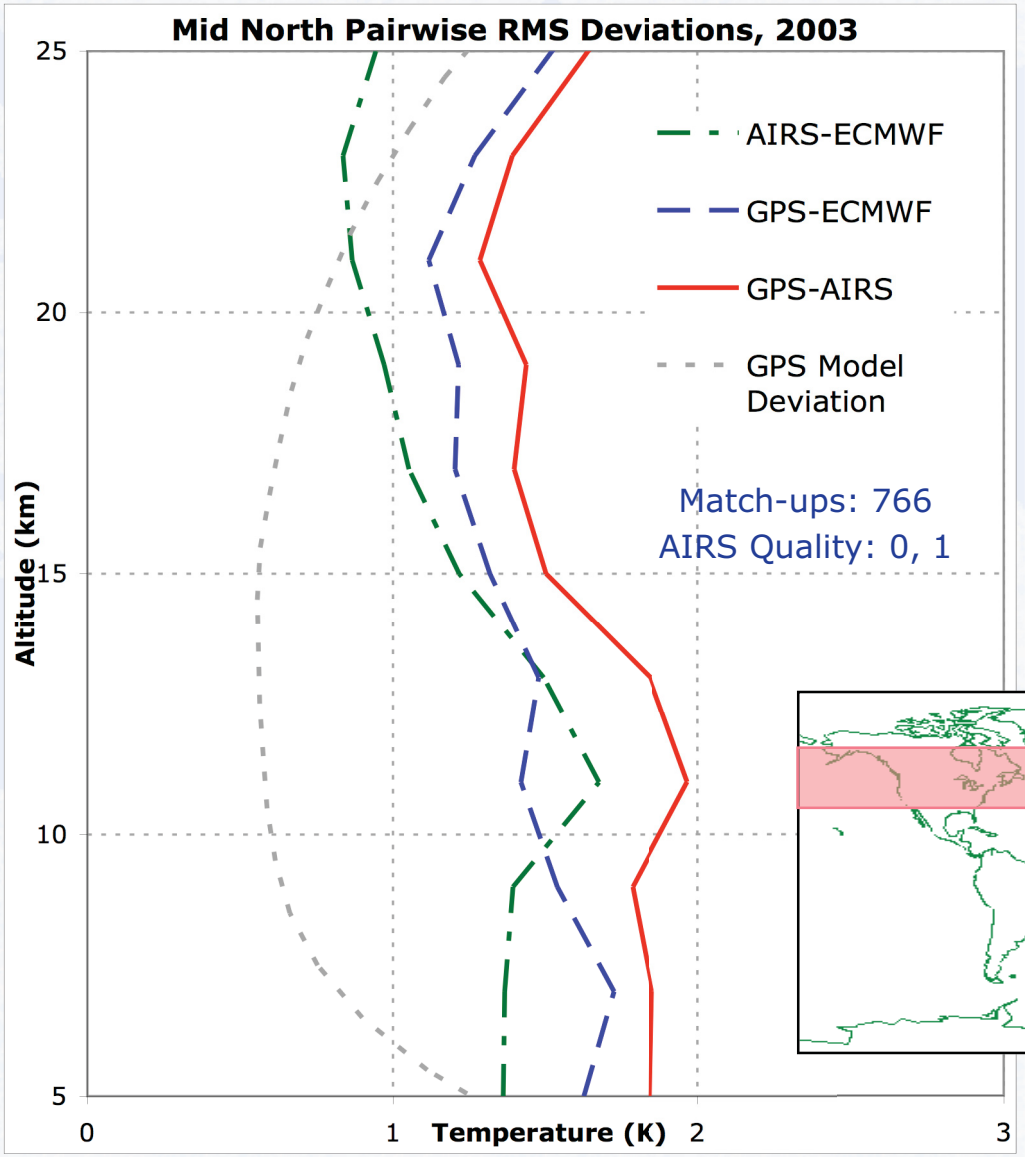
ECMWF
"Sweet Spot"



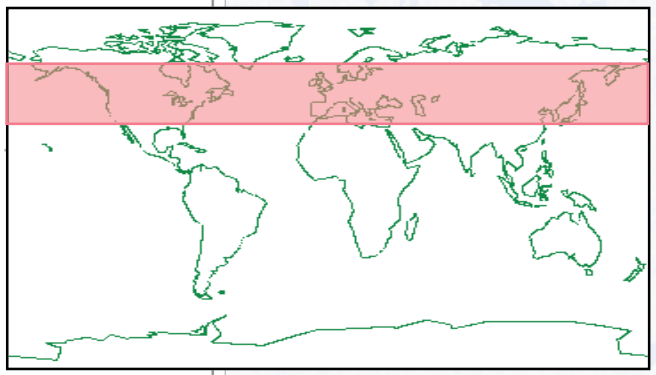
First comparisons:
30°-60° North
("Mid North")

Match-up criteria: <200 km, <2 hrs apart

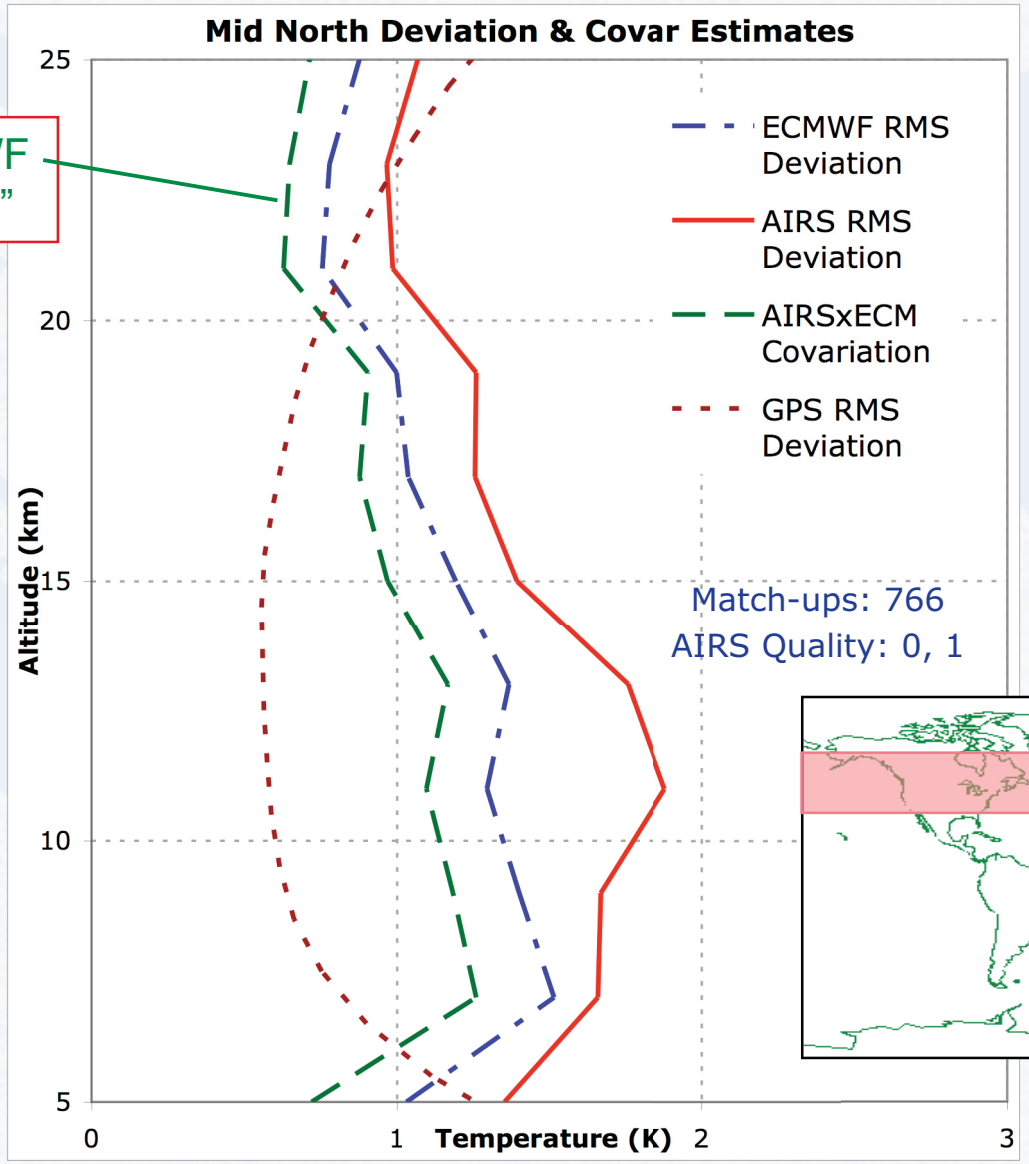
Pair wise RMS deviations



A Puzzle



Derived AIRS & ECMWF RMS Deviations

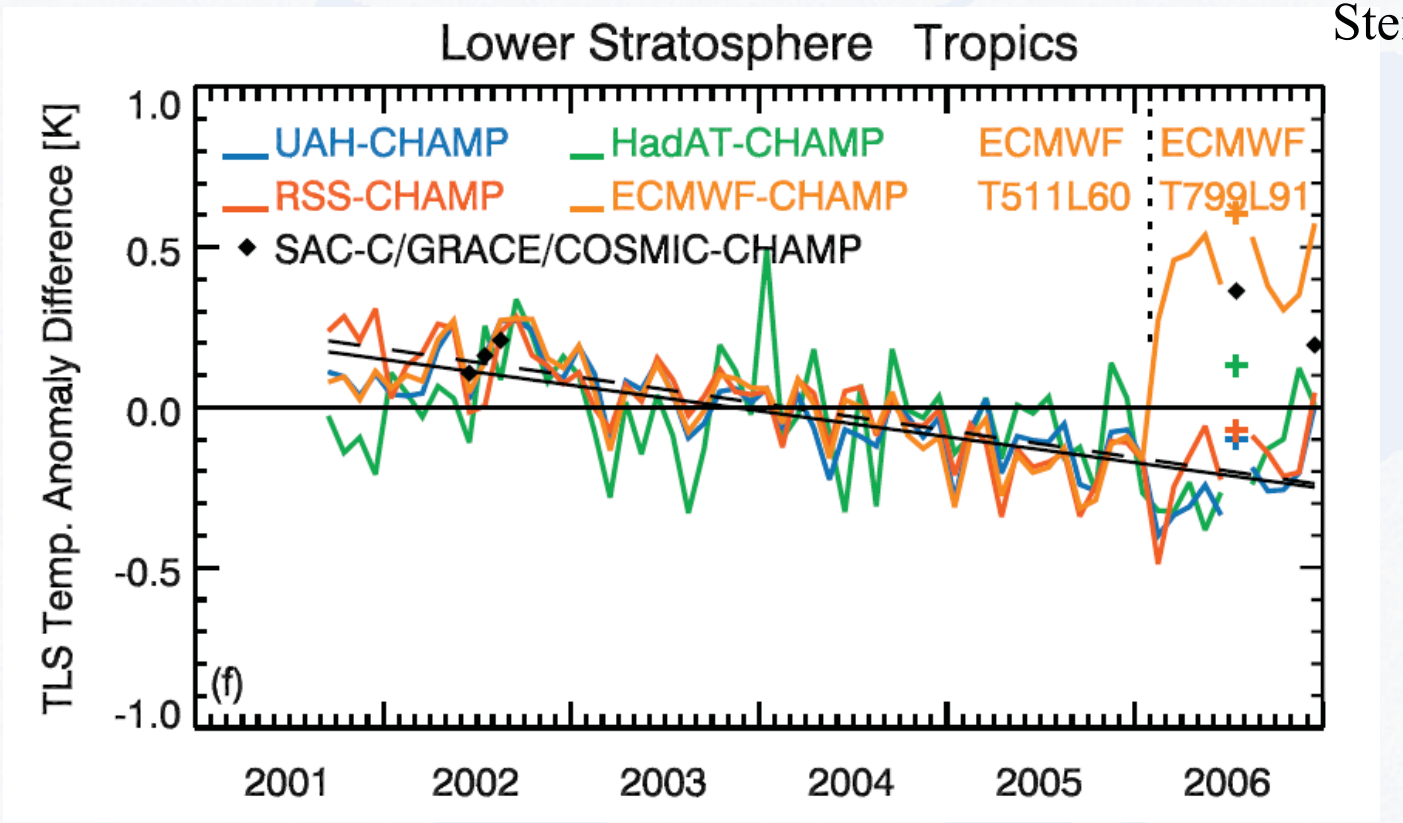


AIRS-ECMWF "Covariation"

Resolution: If AIRS-ECMWF profiles are correlated

"Use of Radio Occultation to Evaluate Atmospheric Temperature Data from Spaceborne Infrared Sensors" Thomas Yunck, Eric Fetzer, Tony Mannucci, Chi Ao, Bill Irion, Brian Wilson, and Gerald Manipon, *Terrestrial, Oceanic and Atmospheric Sciences (2008), in press.*

GPS & Microwave Sounders



Steiner et al., 2007

Discernable difference in anomaly trends:
CHAMP (RO)
RSS
UAH
2001-2006

Steiner, A. K., G. Kirchengast, M. Borsche, U. Foelsche, and T. Schoengassner (2007), "A multi-year comparison of lower stratospheric temperatures from CHAMP radio occultation data with MSU/AMSU records," *JGR*, doi:10.1029/2006JD008283.

Temperature Comparison To Sonde

- **Multi-year statistical profile comparison**
- **IGRA database**
- **CHAMP RO**

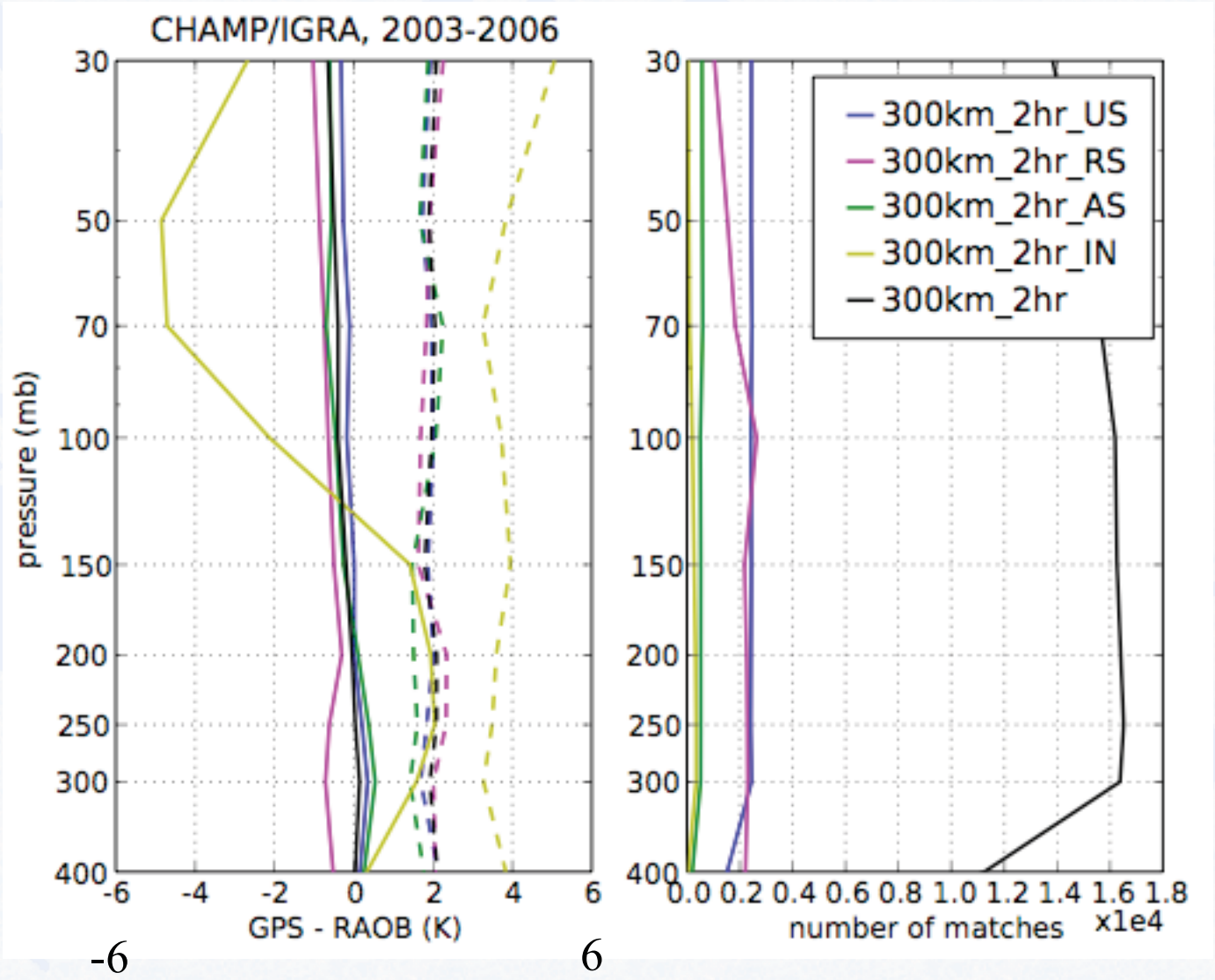
<u>Continents:</u>

USA

Russia

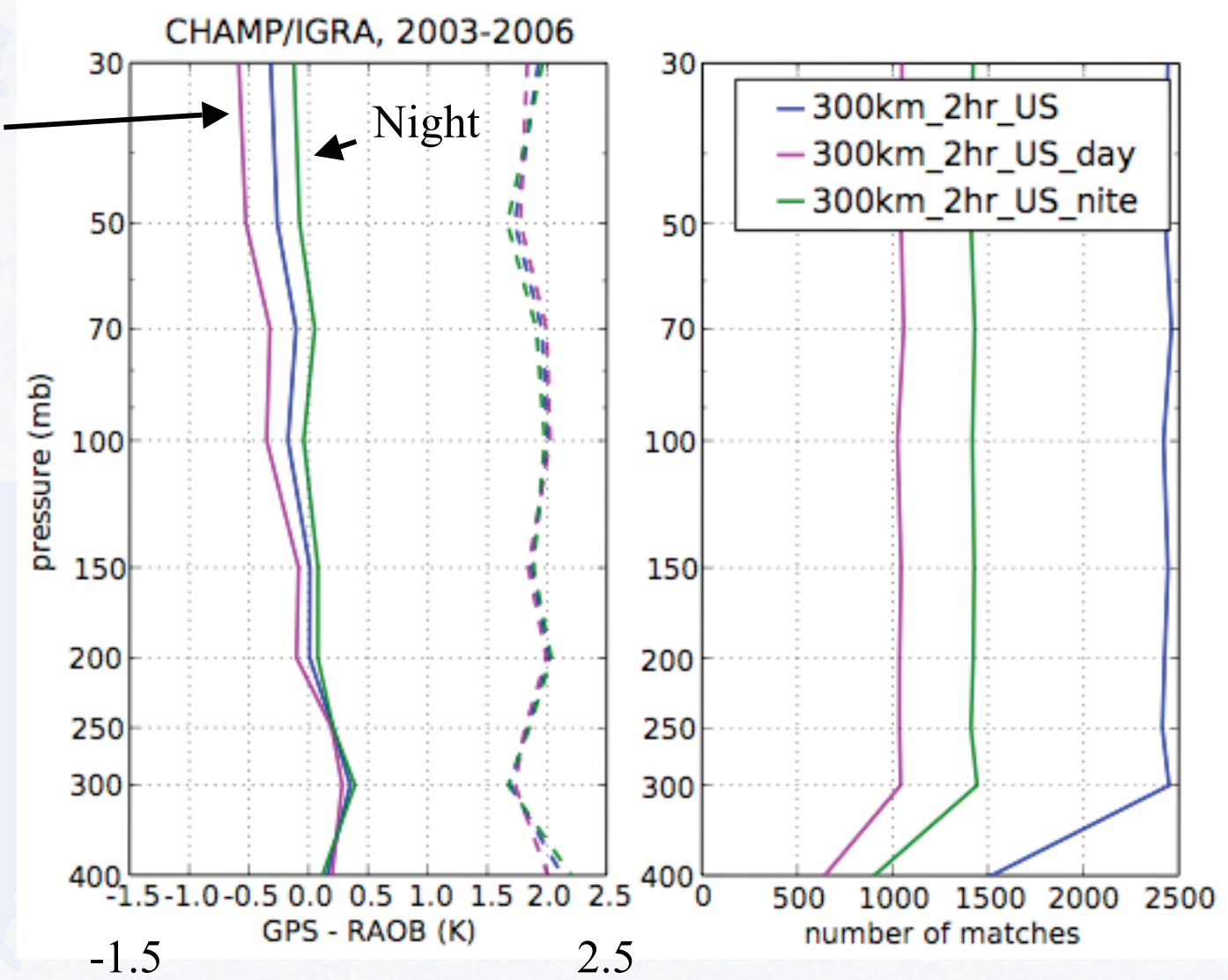
Australia

India



Temperature Comparison To US Sonde

- **Statistically significant difference in daytime versus nighttime means**



GNSS Science Team

- **PBL height climatology**
- **Small-scale variability (waves) UTLS**
  - **Combine GPS RO and A-Train**
- **Improved understanding of turbulence**
  - **Troposphere, stratosphere, ionosphere**
- **Wave dynamics in the tropical tropopause**

High vertical resolution & coherence

- **Improve weather predictions and analyses in the tropics**

COSMIC data in cloudy regions

- **Cyclones over the West Antarctica ice sheet**

COSMIC polar coverage

- **Ocean/Ice/Land remote sensing**

New techniques

http://nspires.nasaprs.com *GNSS Remote Sensing Science Team*

Summary and Conclusions

- **Accuracy: physical retrievals based on time measurement**
  - **Refractivity near PBL up to ~30 km**
  - **Temperature 8-25 km**
  - **(Water vapor probably not SI-traceable accurate)**
- **CLARREO: complements radiances**
  - **Retrievals and radiances needed to test climate models**
- **Integrated into broader observing system**
  - **AIRS, Radiosonde, Microwave**
- **GNSS science**
- **COSMIC/FORMOSAT-3 (6 satellites) and follow on constellations continuously deployed to the long-term benefit of the Earth science community**
- **GPS continues to evolve ⇒ GNSS**